

**Final Report on NASA Grant NAG5-6941:
Continued Investigations of the Accretion History of Extraterrestrial
Matter over Geologic Time
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PI

Kenneth Farley
Division of Geological and Planetary Sciences 170-25
California Institute of Technology
1200 E. California Blvd.
Pasadena, CA 91125

Grant Period

4/1/98-3/31/01

Research Summary:

This grant supported our ongoing project to characterize the accretion rate of interplanetary dust particles (IDPs) to Earth over geologic time using ^3He as a tracer. IDPs are derived from collisions in the asteroid belt and from disaggregation of active comets. Owing to their small size (few to few hundred μm diameter) these particles spiral into the sun under Poynting-Robertson drag typically in less than a few tens of kyrs. Thus IDPs must be continually resupplied to the zodiacal cloud, and because the processes of IDP production are likely to be sporadic, time variation in the IDP accretion rate to Earth is likely to be time-varying. For example, major asteroidal collisions and comet showers should greatly enhance the IDP accretion rate. Our ultimate objective (still ongoing) is to document this time variance so as to better understand the history of the solar system, the source of IDPs accreting to Earth, and the details of the mechanism by which particles are captured by Earth.

To document variations in IDP accretion rate through time we use ^3He as a tracer. This isotope is in extremely low abundance in terrestrial matter, but IDPs have very high concentrations of ^3He from implantation of solar wind ions. By measuring ^3He in seafloor sediments, we can estimate the IDP accretion rate for at least the last few hundred Myrs. Under an earlier NASA grant we identified the existence of a large increase in ^3He flux in the Late Eocene (35 Myr ago), coincident with the two largest impact craters of the Cenozoic Era. The simplest interpretation of this observation is the occurrence of a shower of long period comets at that time, simultaneously increasing the impact cratering probability and accretion rate of IDPs to Earth (Farley et al., 1998). Comet showers produced by stellar perturbation of the Oort cloud should be fairly common in the geologic record, so this is not an unreasonable interpretation of our observations.

The major results from this grant period have been published as follows:

1. Mukhopadhyay, S., Farley, K. and Montanari, A., 2001. A short duration of the Cretaceous/Tertiary boundary event: evidence from extraterrestrial helium-3. *Science*, 291: 1952-1955.

2. Mukhopadhyay, S., Farley, K. and Montanari, A., 2001. A 35 Myr record of helium in pelagic limestones: implications for interplanetary dust accretion from the early Maastrichtian to the Middle Eocene. *Geochimica et Cosmochimica Acta*, 65: 653-669.
3. Farley, K.A., Extraterrestrial Helium in Seafloor Sediments: Identification, Characteristics, and Accretion Rate over Geologic Time, *in* Peucker-Ehrinbrink, B., and Schmitz, B., eds., *Accretion of Extraterrestrial Matter Throughout Earth's History*: in press (2001) (Review Article)
4. S. Mukhopadhyay, PhD Dissertation, California Institute of Technology; to be completed July, 2001.

Details of Work Completed

1. Cretaceous-Tertiary (K/T) Boundary

As discussed above, two impacts in the Late Eocene are associated with enhanced IDP flux, consistent with the occurrence of a comet shower. We wished to test the possibility that the largest known impact of the last few hundred Myr was also associated with a comet shower. We analyzed ^3He in sedimentary rocks from the well-studied Gubbio section in the Italian Apennines. As we recently reported (Mukhopadhyay et al., 2001a), there is no elevation in ^3He associated with this impact. This result suggests that the K/T impactor was not a member of a shower of long-period comets; however it could have been a lone comet, which alone would not greatly enhance the abundance of IDPs accreting to earth.

In the absence of an increase in ^3He accretion from the impactor, we were able to use ^3He as a sedimentation rate proxy. This allowed us to quantitatively establish the depositional interval associated with the 2 cm thick “boundary clay” across which the major K/T faunal succession occurs. Our results strongly suggest deposition in ~ 10 kyr, at the short end of the range of previously proposed values. This result adds a new time-element to studies of the events immediately following the K/T impact.

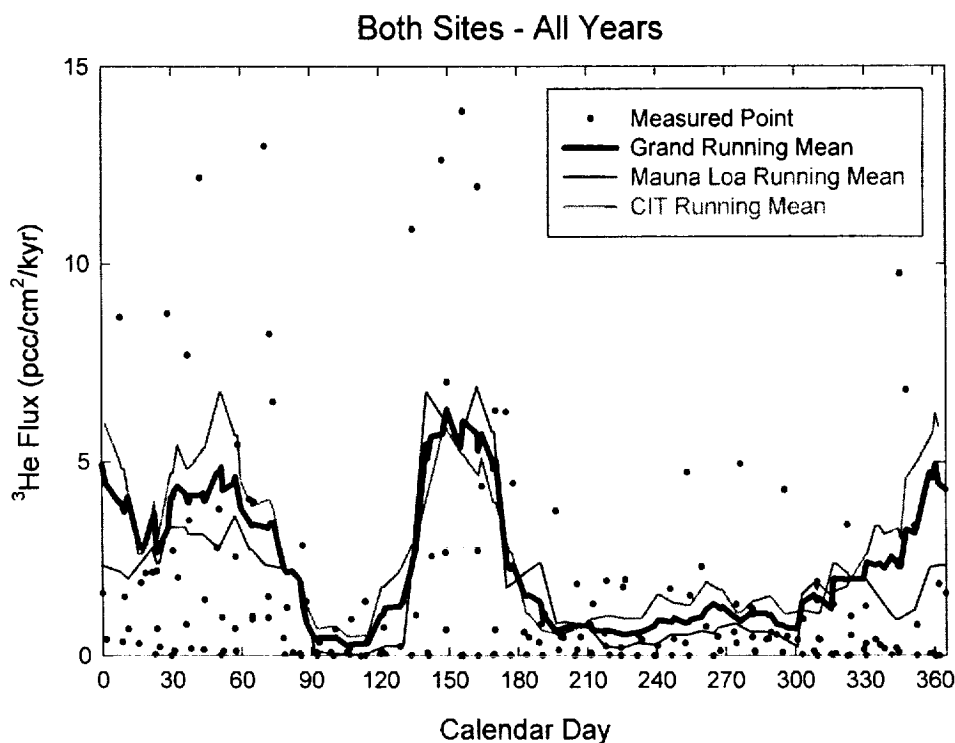
2. Late Cretaceous – Early Tertiary

We also analyzed at high resolution a stratigraphic section spanning 74 to 40 Myr in age to identify any IDP-producing events through this interval (Mukhopadhyay et al., 2001b). Unlike in the Late Eocene, we found only very minor fluctuations in IDP accretion, suggesting the absence of substantial solar system events in this period. This observation essentially precludes the possibility of periodic comet showers of ~ 30 -35 Myr period, a possibility put forward by earlier workers on the basis of the terrestrial cratering record. While theoretical and statistical studies had already weakened the periodic shower possibility, ours are the first observational results bearing on the question, and they strongly rule against it.

3. Fluctuations in IDP accretion over the course of the annual cycle

Since 1997 we have been monitoring the weekly accumulation rate of interplanetary dust in several collectors around the world, with the hope of better understanding what controls the delivery rate of IDPs (and ^3He) to the Earth's surface. Based on model-derived particle sizes, ^3He -bearing particles should transit the atmosphere in < 1 month, so we should be able to resolve fluctuations in terrestrial IDP accretion on roughly this timescale. We believe these fluctuations will provide clues to how Earth's orbital characteristics affect accretion of dust, perhaps through interaction with the Earth's resonant dust ring or through the mutual interaction of the orbits of Earth and the dust particles.

Our most recent results (which include some data collected in the current grant period, rather than just the grant period being described here) are shown in the accompanying figure. The results strongly suggest a large seasonal modulation of the IDP accretion rate, independent of sampling location. Through collaboration with theoreticians we are presently working to interpret these results within the context of IDP orbital evolution models.



References

- K.A. Farley, A. Montanari, E.M. Shoemaker, and C. Shoemaker, Geochemical evidence for a comet shower in the Late Eocene, *Science* 280 (1998) 1250-1253.
- Mukhopadhyay, S., Farley, K. and Montanari, A., 2001a. A 35 Myr record of helium in pelagic limestones: implications for interplanetary dust accretion from the early Maastrichtian to the Middle Eocene. *Geochimica et Cosmochimica Acta*, 65: 653-667
- Mukhopadhyay, S., Farley, K. and Montanari, A., 2001b. A short duration of the Cretaceous/Tertiary boundary event: evidence from extraterrestrial helium-3. *Science*, 291: 1952-1955.